Tilburg University

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James, M.J.

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An Institutional Critique of Recent Attempts to Measure Technological Capabilities across Countries

Jeffrey James

This paper will be guided by recognition of two points, both of which feature prominently in institutional economics, or, as it is sometimes called, institutionalism. The first point has to do with the centrality of technology to economic growth and development, while the second concerns the inappropriateness of technological and other concepts developed in rich countries for the very different circumstances prevailing in the poorer countries. Let us deal with each of these recognitions in turn.

For two of the best-known early proponents of institutionalism, Clarence Ayres and Thorstein Veblen, the role of technology in the dynamic processes of growth and development was nothing short of overridingly important. "Ayres," for example, "placed more emphasis on technology than on any other factor which contributed to economic development" (Cypher and Dietz 2004, 172). Indeed, "For Ayres, technological progress and economic development were virtually synonymous" (172). Writing at the turn of the century, Veblen was no less insistent on the importance of technology and technological change in the evolutionary process of cumulative change in the economy. He "emphasized the role of technological change, broadly defined to include both hardware and know-how. He stressed industrial arts to a point that bordered on determinism. The adage, necessity is the mother of invention, was reversed; invention had become the mother of necessity" (Clark and Juma 1990, 211). In the more recent "new institutional economics," moreover, some authors continue to emphasize the dominant role of technology in creating the potential for economic growth and development. To Douglass North, for example,

> The second economic revolution which began in the second half of the nineteenth century was the systematic application of the modern scientific dis-

The author is Professor of Development Economics at Tilburg University, The Netherlands.

> ciplines to technology and more broadly to the economic problems of scarcity. For those economies that could realize their potential the productivity implications have resulted in standards of well-being simply unimagined by prior generations. (North 1993, 4)

By now, a large body of empirical evidence has confirmed that economic growth does indeed depend heavily on technological change (Denison 1962), but this evidence also points to wide variations in growth rates across countries. The focus of this paper on technological indices can thus be viewed as an attempt to understand why some countries are able to exploit the benefits of modern technology, while others plainly lack the ability to do so (most notably, but not exclusively, countries in sub-Saharan Africa).

Also heavily undergirding the paper is, as noted above, the recognition that concepts designed for the rich countries may be inappropriate to the conditions prevailing in the majority of poor countries that comprise the Third World. From our particular point of view, this problem has to do with technology concepts that are transferred, as is, from rich to poor countries. Irrespective of the specific concept at issue, however, this second recognition is usually based on a rejection of the claim to a "monoeconomics," an economics, that is to say, which purports to apply with equal relevance to countries at very different stages of development. Among the many development economists who reject this claim to a universally applicable form of economics, two of them warrant special mention for their well-known contributions that were published in the 1960s. In the *Asian Drama* (1968), Gunnar Myrdal presented a highly detailed and convincing account of the dangers involved in applying a "Western approach" to the development problems in South Asia. "Economic theorists," he argued, "more than other social scientists have long been disposed to arrive at general propositions and then postulate them as valid for every time, place and cultures" (6). Across a wide range of development issues, Myrdal showed how this line of thought can lead to problems of mismeasurement and policy errors in the countries belonging to South Asia. In a similar vein, an influential article written by Dudley Seers (1962) points out the implausibility of deriving general propositions from the experience of relatively few industrialized economies, which, seen from a global perspective, exhibit an exceptional range of characteristics. (The typical case, by contrast, is a poor, largely rural economy, whose characteristics are very much the rule, rather than the exception, at the global level). Seers suggested, accordingly, that those who focus (in, say, teaching) on the relatively unusual, developed countries need constantly to stress the limitations of what is, in effect, a very special case.

Technological Indices and the Rural Sector

If any general policy conclusion can be drawn from the need to meet the Millennium Development Goals (MDGs) by the year 2015, it is that attention will need to focus heavily on rural, rather than urban, areas of developing countries. Within the former sectors, moreover, it is equally clear that one will need to single out the poorest members, who tend to suffer most acutely from the problems that the MDGs seek to redress. (The Millennium Development Goals are to eradicate extreme poverty and hunger, achieve universal primary education, promote gender equality and empower women, reduce child mortality and improve maternal health, combat HIV/AIDS and other diseases, ensure environmental sustainability, and develop a global partnership for development).

It is not that these recognitions have been entirely lost on the development community. According to UNESCO, for example,

> many, if not all, of the . . . Millennium Development Goals require special attention to the situation of rural populations. In spite of rapid urbanization, *three billion or 60 per cent of the people in developing countries . . . still live in rural areas.*
>
> *Three quarters of the world's poor, those earning less than a dollar a day, live in rural areas.* One in five children in the South still does not attend primary school and, while rural-urban statistics on education are scarce, many countries report that non-attendance in school, early dropout of students, adult illiteracy and gender inequality in education are disproportionately high in rural areas, as is poverty. (Emphasis added)

As regards the necessity for rural policy to focus on particular disadvantaged groups, an influential figure in the field has suggested, for example, that

> The productivity on small farms in developing countries must increase if the Millennium Development Goals for poverty and hunger are to be archived. . . . Increasing productivity, which reduces unit costs of production, can help poor farmers and farm workers out of poverty and hunger, generate employment and incomes in non-farm rural enterprises, and it can make available more food to poor consumers at lower prices. (Pinstrup-Andersen)

Yet, in spite of these and other recognitions that could be cited, the required re-allocation of policy concern in favor of rural areas does not appear to be happening on anything like the scale that is needed in most developing countries. In fact, with regard to many policy areas, it is difficult to discern any movement at all (Eastwood and Lipton 2000). Nor, in the realm of data collection and measurement, does the pronounced degree of urban bias seem any less acute than it traditionally has been. Our concern in this paper is not with these large and important problems as a whole but rather with one recent strand of literature in the realm of technology and development that, thus far, has shown scant if any inclination to involve the sector with the most relevance to the MDGs. I am referring here to the urban and developed country bias embedded in recent attempts to measure the technological capabilities of developing countries, on the basis of indicators that are also, or more accurately, especially suited to the richest countries.)[2] The problem is thus not resident in the use of national level data per se. It resides rather in the choice of indicators that are used at this level to measure technology capabilities. If, for example, the country level data happened to be about fertilizer use, it would obviously refer more to rural than urban conditions. The problem is rather that the indicators used in recent attempts to measure national technological capabilities supply almost entirely information of the opposite kind. That I view this information as being mostly unhelpful is a matter of values and development perspectives, but even when they are evaluated on their own terms, these indicators perform poorly in discriminating among many poor countries, whose scores on indices such as patents, high-technology exports, and internet hosts tend to be zero or negligible. In other words, my problem is partly that the UNDP could better spend its time on indices that more closely accord with its mandate, but also that the goals of the TAI are themselves not met. These goals are best expressed in the words of the UNDP itself. Thus:

> The design of the index reflects two particular concerns. *First, to focus on indicators that reflect policy concerns for all countries, regardless of the level of technological development. Second, to be useful for developing countries. To accomplish this the index must be able to discriminate between countries at the lower end of the range.* (UNDP 2001, 46; emphasis added)

In expanded form, the criticisms that have just been espoused form the first part of the paper and they are advanced mainly toward one of the numerous indices now in existence: to wit, the Technology Achievements Index proposed by the UNDP (2001). I have chosen to focus on this particular index partly because it sits so oddly with the well-known emphasis of the UNDP on problems of human development that are disproportionately represented in rural rather than urban areas and from whom one may thus have expected some attention to be paid to the technical achievements in those same areas. This critique is followed in the second, more constructive, part of the paper, by an attempt to modify the TAI on one hand and to identify elements of an alternative, rural-biased approach to measuring technical achievements on the other. More specifically, I shall attempt in the latter case to shift the focus from ownership of toward access to technology; from indicators that include rather than exclude the poorest developing countries; from high-technology indicators that cater to a tiny majority of the population to indicators that bear on, for example, the capabilities of small farmers; and from indicators that pay no special attention to gender to those that do. For the specific indicators that are deemed to form part of this shift, a search for cross-country data is undertaken partly with the aim of determining what data already exist, what they reveal, and how they may need to be altered.

A Critique of the TAI (and Other Similar Measures of Technological Achievement)

Other things being equal, an index that includes developed, as well as developing, countries is preferable to a measure that is relevant to just one country grouping. The former type of index is perhaps best exemplified by the Human Development Index, which is able to rank more than 160 countries, because each of its components (such as infant mortality and life expectancy) is applicable as much to rich as to poor country groupings. Indeed, it is at least partly due to this widespread applicability that the HDI has become one of the most widely used cross-country measures in the entire field of development studies.

The situation is entirely different, however, when, in the construction of an index, a bias is introduced through the selection of indicators that are relevant to one group of countries but much less so, if at all, to another group. In the case of the TAI, my contention is that it embodies a strongly developed country bias in the choice of indicators and that this bias has a number of important implications for the measurement of technological capabilities in the Third World. The first implication is that the choice of indicators relating, for example, to the creation of technology is so rarely relevant to the majority of poor countries (where only a relatively small amount of R&D is undertaken) that they do not engage the attention of institutions in the countries whose task it is to collect statistics at the national level. This, in turn, has the effect of excluding countries from the TAI that do in fact have some capabilities in the activities in question. (As we shall see below, the exclusion of developing countries is a problem that acutely besets the TAI). Even where the necessary data are available, moreover, they are often so low as to rob the index of its discriminatory power (most especially for countries below a certain level of per capita income). The final problem, to which I have alluded above, is that the developed country bias of the TAI translates, within given countries, into an urban bias, since it is generally the urban sector that most closely reflects the conditions prevailing in the rich countries. And this latter bias, in turn, implies that technological capabilities in areas of the economy less reflective of conditions in developed countries are ignored. Yet, as also noted above, it is precisely those other (predominantly rural) areas of the economy that bear most heavily on the likelihood of meeting the MDGs.

Let me begin our discussion of these issues by describing the various elements that comprise the TAI and explaining why I think many of them are subject to developed country bias (and by extension to urban bias). As a general basis for our critique, I should note, however, that the earlier debate over appropriate technology is no less important than, and indeed overlaps with, the urban/developed country bias. For, in that debate, the major theme concerns the suitability of techniques from developed countries to developing countries, where, among other differences, labor is abundant relative to capital and the price of the former tends, accordingly, to be low in relevant to the latter. The topic of this paper is technological capabilities rather than technological choice, but the debate over the latter is a clear antecedent of the criticism that will be advanced below in relation to the former.

Table 1. Dimensions and Indicators of the TAI

Dimension	Indicators
Creation of technology	(a) Patents granted per capita (b) Receipts of royalty and license fees from abroad per capita
Diffusion of recent innovations	(a) Internet hosts per capita (b) High and medium technology exports as a share of all exports
Diffusion of old innovations	(a) Logarithm of telephones per capita (b) Logarithm of electricity consumption per capita
Human skills	(a) Mean years of schooling (b) Gross enrollment ratio at tertiary level in science, mathematics, and engineering

Source: UNDP 2001, 47.

The Role of Developed Country Bias

The four major dimensions of the TAI and the indicators associated therewith are shown in table 1.

It bears emphasizing at this stage that neither the dimensions nor indicators shown in table 1 differ substantially from other recent attempts to measure technological capabilities across a wide sample of countries.[3] The Technology Capabilities Index (ARCO) compiled by Archibugi and Coco (2004b), for example,

> [t]akes three dimensions of technology into account: a) *innovative activity* (based on patents registered at US patent office and scientific publications); b) *technology infrastructure* (including old and new ones and based on Internet; telephone mainlines and mobile, and electricity consumption); c) *human capital* (based on scientific tertiary, enrolment, years of schooling and literacy rate). (7)

To an apparently large extent, therefore, the charge that the TAI is subject to a developed country urban bias seems applicable to the other recently developed measures as well.[4] The nature and consequences of this form of bias have been most thoroughly explored by Myrdal (1968) in his *Asian Drama,* which concludes that "when theories and concepts designed to fit the special conditions of the Western world . . . are used in the study of underdeveloped countries in South Asia, where they do not fit, the consequences are serious" (17). One example of this general danger arises "from the neat division of income into two parts, consumption and saving," which is clearly plausible "in Western societies where the general levels of income and a stratified system of income redistribution by social security policies and other means have largely abrogated any influence on productivity" (19). In many developing countries, on the other hand, so neat a conceptual distinction does not, as Myrdal pointed out, apply to groups living in poverty. Essentially, the reason he gave is that for many such groups poverty tends to be accompanied by malnutrition and a consequent inability to work productively. Because of this relationship, Myrdal further suggested that expenditure on food may often exert an influence on productivity and growth that needs to be recognized at micro and macro levels of analysis. If, however, the conceptual separation of savings and consumption continues to be made, the extent of developed country bias might, in his view, indeed be considerable.

To what extent, then, do the defining concepts and measures of the TAI, shown in table 1, reflect developed rather than developing country conditions and, if so, what are the consequences? This question can be most easily answered, I feel, in relation to the concept of "technology creation," which is measured in terms of patents and royalties. For it is this dimension of table 1 that is almost entirely dominated by rich countries, which, in 2001, held 97 percent of all global patents (to whom the vast majority of royalties and license fees must, accordingly, have accrued). The question that then arises has to do with the consequences of using so blatantly biased a measure of technological capabilities in an index that purports to cover developing as well as developed countries (a bias that, in assuming all countries strive to meet the same goals, exactly parallels what Myrdal had in mind).

Technology Creation

Arguably, the major consequence is that the exclusive focus on technology creation, diverts attention of resources from the far more fundamental capabilities associated with the use and assimilation by developing countries, of precisely the innovations described in the previous paragraph. The need for acquiring these assimilative technological capabilities has been clearly described by Carl Dahlman and Larry Westphal (1982, 105) in the following terms:

> The exploitation of technological knowledge is central to the development process. Less-developed economics typically obtain this knowledge from more advanced ones rather than by creating it themselves. This is to be expected, given the vast pool of foreign technological knowledge available to them for exploitation. It does not follow, however, that technological effort has only a minor role to play in the process of industrial development. Such an inference would only be valid if technological effort were conceived narrowly, as the employment of resources solely for the purpose of creating new knowledge. In fact, however, *resources are also needed for the task of learning to make effective use of existing knowledge.* It is in this broader and more realistic sense that the term "technological effort" is used . . . i.e. as the employment of resources not just to create technical knowledge, but also to master it.

As it is, developing countries, especially those in sub-Saharan Africa tend to underestimate the crucial role that needs to be played in building local capabilities to make effective use of foreign technologies. If such countries take the TAI seriously, they will find no reason whatever to alter their existing technological proclivities, since only the creation of patentable technology is capable of raising the value of this index. (It is worth noting here that no such problem arises in relation to the HDI, whose components are just as important, if not more so, to developing, as opposed to develop, countries. The HDI, that is to say, does not suffer from the pronounced type of developed country bias that afflicts the technology creation component of the TAI). Contrary to what the UNDP seems to believe, it is simply *not* the case that *all* countries view the need to increase the number of patentable innovations as a relevant policy goal.

Diffusion of the Internet

Turning now to the second dimension of the TAI, developed country bias can again be detected, as can the attendant dangers of focusing policy attention too heavily on just spreading technology as widely as possible, within developing countries. I am referring here specifically to the use of Internet hosts per capita as a measure of the diffusion of recent innovations (where the term *Internet hosts* refers essentially to the number of computers in the economy that are directly linked to the worldwide Internet network). In order to identify the developed country bias associated with this measure, one has first to recognize that the adoption and diffusion of new products and technologies are *not* ends in themselves. For, as Amartya Sen (1985) has persuasively argued, what matters to the individual user of commodities and technologies occurs after they have been purchased or supplied. What matters, in other words, is how goods and technologies are actually used. And whereas one can reasonably assume that the majority of those living in the rich industrialized countries possess the capabilities to derive much of what an Internet-connected computer has to offer, this is certainly not an assumption that can be made in much of the Third World (where in some cases, even a large increase in the number of Internet hosts is not accompanied by a corresponding increase in well-being). Indeed, the relationship between the diffusion of Internet hosts and individual welfare then becomes highly variable, even though, in the description of the TAI, no recognition to this effect can be found. Instead, a much simpler line of reasoning is evinced, namely, that "All countries must adopt innovations to benefit from the opportunities of the network age" and that "This is measured by diffusion of the Internet" (UNDP 2001, 46).

In the most extreme case, diffusion of additional Internet hosts may have no influence at all on individual well-being. That this is not a mere theoretical possibility is most readily apparent from an extensive evaluation carried out by the Canadian International Development Research Centre, which between 2000 and 2001 sampled some 3,500 respondents from five African countries in 36 telecenters and cyber cafes (the former being essentially donor-funded community access points, offering a range of ICTs, including the Internet, mainly to those living in rural areas (Etta and Wamahia 2003). Table 2, representing the Mozambique case, well illustrates the overall findings of the survey and, in particular, the low percentage of Internet users, even when this service

Table 2. Frequency of Use of Telecenter Services (Mozambique)

Telecenter Services		Frequency of Use											
		5 D/W		3–4 D/W		1–2 D/W		2 D/M		1 D/M		Total	
		M	F	M	F	M	F	M	F	M	F	M	F
Manhiça													
	E-mail	4	0	0	0	9	0	2	0	2	0	17	0
	Internet	4	0	0	0	3	1	3	0	0	1	10	2
	Use of computer	13	7	11	2	8	0	3	0	4	0	39	9
	Telephone	6		9	2	10	2	2	1	1	1	28	9
	Fax	1	0	1	1	0	1	1	1	0	0	3	3
	Photocopies	6	1	11	0	6	1	5	2	7	2	35	6
Namaacha													
	E-mail	3	1	2	0	2	2	1	0	1	1	9	4
	Internet	1	0	0	2	1	1	1	0	1	1	4	4
	Use of computer	9	2	1	2	5	5	1	0	1	0	17	9
	Telephone	12	10	16	8	11	9	3	0	0	1	42	28
	Fax	2	1	0	0	1	2	0	0	0	0	3	3
	Photocopies	12	4	3	6	27	4	4	5	2	9	58	38

Source: Etta and Wahamiu 2003.

Notes: D = day, W = Week, M = Month, M = Male, F = Female, D/W = Days per week, D/M = Days per month.

was readily available to the community at large. In Mozambique, as in the other countries, moreover, "[u]sers are shown to have been disadvantaged on the basis of age, gender, education, literacy levels, and socio-economic status" (Etta 2003). This finding, I should note, is entirely consistent with the notion that individuals living in circumstances most *unlike* those prevailing in the developed countries will tend to benefit least from the technologies designed in and for precisely those latter conditions (a notion that, however, runs totally counter to the central tenet of catch-up theory, namely, that the most backward countries will benefit most from the technologies already available in the developed countries).[5]

In common with the first dimension of the TAI, therefore, the diffusion of Internet hosts does not in itself mark the technological achievements that really matter to most developing countries, such as the capability to adapt and use foreign technologies effectively (which, as noted below, *could* be captured by total factor productivity measures). And again in analogy with technology creation, there is a danger that the focus of the TAI on Internet diffusion will deflect policy attention away from those more fundamental technological capabilities.[6] In numerous developing countries, for example, indigenously designed projects have arisen which greatly multiply the benefits from a single Internet host. One of the best known of these is the Kothmale Internet Project in Sri Lanka, which uses community radio to bring the benefits of the Internet to large numbers of rural inhabitants. In particular, browsing the Internet during special radio programs involves the local community in an essential way, as the following citation clearly reveals. Thus,

> In Kothmale . . . [t]he daily programmers respond to queries from listeners. Presenters first select relevant, reliable websites and broadcast the program with local resource persons as studio quests (e.g. doctors for a health program) who discuss the contents of the mostly English-language sites directly in the national languages. They also describe the websites and explain how they are browsing from one web page to another. Thus, listeners not only get the information they requested, but they understand how it is made available on the web. They can respond to the program and they know that essential data will remain available in the community database if they wish to make individual use of it. (Hughes 2003, 2)

Most examples of multiplying the impact of an Internet connection, however, are to be found in India, where an impressive array of local initiatives use intermediaries, rather than diffusion of Internet hosts, to reach millions of villagers. An intermediary in this sense is someone who is familiar both with the technology and the characteristics of the community that makes use of his or her services, more often than not, in the context of a small, rural kiosk (James 2004).

Diffusion of "Old Innovations"

Based on what has already been said, one might expect "older" innovations such as telephones to present fewer problems of developed country bias than were described in the previous section on the diffusion of the Internet. For, as I suggested there, it was at least in part the novelty and complexity of the technology that created welfare problems for members of society lacking the necessary user capabilities (such as high literacy and language skills, computer literacy, and technical competence). Telephones, on the other hand, require only the most basic user capabilities and are thus less susceptible to this particular form of developed country bias (as is often also the case with many second-hand products and techniques imported for use in developing countries, because they are more appropriate in this sense than the most modern vintages available in the developed world). Viewed historically, the point being made is that older goods and techniques were introduced at a time when socio-economic conditions (e.g., incomes, skills, technological complexity, and so on) were closer in many ways to contemporary circumstances in the Third World. As such, these goods and techniques are less likely than contemporary vintages to bypass those most acutely in need of the benefits from technical change (Stewart 1977).

On the other hand, however, the particular indicator chosen to reflect telephone diffusion in the TAI does contain a developed, rather than a developing, country view of how this mode of communication is actually used in the society. For, whereas in developed countries, use of telephones occurs overwhelmingly on the basis of individual ownership, in rural and informal urban parts of developing countries it is very largely through public payphones that usage takes place. And when this latter pattern of access

Table 3. Village Phone Access versus Total Number of Phones per Head of the Population

Country	Village Population[a]		National Population
	Total with Access to Phone (0005)	Percentage with Access to Phone	Telephones (Mainline and Cellular, per 1,000 People)[b]
Bangladesh	31,420	30	5 (.005 per person)
Bhutan	n/a	n/a	18 (.018 per person)
India	726,827	98	28 (.028 per person)
Maldives	196	100	90 (.090 per person)
Nepal	8,754	45	12 (.012 per person)
Pakistan	29,357	30	24 (.024 per person)
Sri Lanka	9,834	75	49 (.049 per person)
Total	806,388	83	

Sources: For the village population, Minges and Simkhada 2002; or telephones, ITU 2002.

[a]Data relate to 2002.

[b]Data relate to 1999.

is taken into account, even in rural areas of developing countries, the proportion of inhabitants that enjoy telephone use (albeit less conveniently than through private ownership) can be remarkably high.

Consider, for example, data contained in table 3 for a selected sample of South Asian countries.

Table 3 is divided into two parts, one of which is concerned with estimates of rural access to phones and the other with the TAI data for telephone diffusion in the same sample countries. The Indian case is particularly striking for our purposes because the country has achieved (almost) complete access in spite of its relatively low income per head, large size, and minute number of telephones per head (as indicated by the TAI value). Much of this success, it seems, can be attributed to the government, which, in the 1990s "launched a major program to increase public access to telephone service in all areas of the country. One goal of the program was to install a public telephone in each of India's approximately 600,000 villages. . . . Another goal was to set up public call offices (PCOs) in both rural and urban areas. More than 1 million PCOs had been established by 2002" (Encarta Online Encyclopedia, "India," http://encarta.msn.com). It bears emphasis in this regard that in spite of similar numbers of telephones and income per head, India enjoys more than three times the percentage village access to telephones than does Pakistan.

Turning specifically to mobile phones, which are growing most rapidly in Africa, one has again to take into account the way in which these products are used in developing countries. Specifically, it appears that even in the poorest locations, there is a considerable amount of sharing mobile phones. One estimate cited in support of this contention is that 97 percent of Tanzanians claim to have access to mobile telephony.

Human Skills

Both indicators of human skills adopted in the TAI—"mean years of schooling" and "gross enrolment ratio at tertiary level in science, mathematics and engineering"—suffer from the same weakness that was described above in relation to the Internet indicator, namely, that they say nothing about the actual achievements derived from these educational "inputs." For, in just the same way that a given commodity or technology can have widely different effects, depending, among other things, on how they are used, so too may a certain number of school years endow different individuals with very different "functionings" (a term owed to Sen (1985)).

Recent data compiled by the *Trends in International Mathematics and Science Study* (2003), for example, reveal that even among OECD countries there are quite striking differences in mathematical and scientific achievements at both the fourth and eighth grade levels. For developing countries, data are collected primarily by the UNESCO-UNICEF Monitoring Learning Achievement (MLA) project, which also focuses on the fourth and eighth grades. At the former level, the project covers mainly African countries and deals with three dimensions of educational achievement, namely,

Table 4. Percentage of Grade 4 Pupils Who Attained the Minimum Level of Mastery Learning, Selected African Countries,* 1999

Country	Literacy	Numeracy	Life Skills	Combined
Botswana	46.2	55.4	71.8	57.8
Madagascar	56.9	34.4	97.3	66.1
Malawi	15.3	30.7	95.4	54.9
Mali	50.4	37.9	69.8	54.4
Mauritius	77.6	70.3	71.6	70.3
Niger	39.3	15.3	44.9	25.6
Senegal	45.6	22.9	36.3	31.2
Uganda	64.3	41.9	78.8	54.4
Zambia	37.8	19.9	49.0	31.9

Source: Chinapah 2003.

*Minimum mastery levels were established for each of the three learning achievements above, in the MLAI survey, which covered grades 4 and 5 for forty-eight countries. That document also defines the three dimensions of learning contained in the table.

literacy, numeracy, and life skills. Table 4 shows how a sample of nine sub-Saharan countries score on each of these dimensions. That is, it shows for each country what percentage of grade 4 pupils attained a specified minimum level of mastery in literacy and life skills. It does not show what is an acceptable percentage for each subject in each country.

Because similarly widespread inter-country disparities in learning achievements are apparent also at the eighth grade level in the same country sample, the number of years in school appears to be a very weak indicator of technological capabilities. And unless this discrepancy is widely recognized by policy makers, there is a real danger that they will be inclined to focus their attention on increasing the quantity, rather than the achievements derived from, education in schools. For many developing countries there is already a tradition of favoring easily measurable education targets. In the *Asian Drama*, for example, Myrdal (1968, vol. III, 1657) observed that "[t]here has been a tendency in all the South Asian countries to think primarily in terms of quantitative targets, such as the number of pupils enrolled in a certain category of schools, and less often in terms of qualitative improvements."

Because it is also stated in terms of educational "inputs" rather than outputs or achievements, the second indicator used by the TAI to reflect skills—the gross tertiary science enrollment ratio—is subject to much the same criticism that has already been leveled against the first indicator (although, arguably, at such a relatively advanced stage of education, variations in achievements may be less pronounced than they appear to be at earlier stages). This second indicator, however, does run into the problem that for many of the poorest developing countries the numbers of students enrolling in science at university are dismally low (partly, perhaps, because of the high costs involved and partly because of the colonial heritage). In almost every sub-Saharan country, for example, the value given in the TAI is less than 1 percent and in many, if not most, cases, less than

0.5. As such, this indicator, in common with several others I have considered, lacks almost any ability to discriminate among a large number of developing countries, in spite of the fact that it is precisely these countries whose technological capabilities most urgently need to be assessed and improved upon. In fact, it is to this particular statistical problem associated with the TAI that I now turn.

The Statistical Manifestation of Developed-Country Bias

Out of a possible 160-odd countries, only 72 are ranked by the TAI. For the unranked majority, "data were missing or unsatisfactory for one or more indicators" (UNDP 2001, 46). It is true that data gaps occur for at least some countries on every indicator, except Internet hosts, for which the International Tele-communications Union maintains a very thorough database. Yet, it is very clear that data gaps are easily the most prevalent among the two indicators chosen to reflect technology creation, namely, patents and royalty/license fees. Since the creation of technology is, as emphasized above, the most egregiously irrelevant concept for the vast number of developing countries, it is scarcely surprising that the excluded group of countries is primarily drawn from the same country grouping. The point to be made here is not that there *are* overlooked or otherwise unrecorded data; it is rather that in the vast majority of cases there simply are no patents or royalties to speak of. Thus it is that by excluding such a large number of developing countries the TAI has seemingly negated the very ideals that were set for it, namely, that it should "be useful for developing countries" and that it "must be able to discriminate between countries at the lower end of the range [of technological development]." An index obviously cannot meet such demands if it is constructed in such a way as to exclude precisely the units that are meant to be studied.

For developing countries that are not excluded from the TAI on the grounds of data unavailability, let us examine how useful and discriminatory are the estimates for indicators that I have argued to be the most biased in favor of developed countries. These are the indicators pertaining to technology creation, Internet hosts, and gross tertiary science enrollment ratios. (Other indicators were also subject to severe criticism but from a different standpoint). Table 5 presents the values assigned to these indicators for the lowest ten (developing) countries in the index.

With the exception of two entries for Nicaragua, the only Latin American country in the group, the t-values are generally very low, as predicted. As such, these entries are not statistically different from the mean of each column and they provide no extra information beyond those numbers.

Toward a Revised or Supplemental Index

From all that has thus far been written, it seems that two main avenues need to be followed in the search for an alternative or a supplement to the TAI. One such avenue

Table 5. TAI Scores on Selected Indicators, Bottom Ten Countries

Country	Patents Granted to Residents	Receipts of Royalties and License Fees	Internet Hosts	Gross Tertiary Science Enrollment Ratio
India	1	(.)	0.1	1.7
Nicaragua	n/a	n/a	0.4	3.8
Pakistan	n/a	(.)	0.1	1.4
Senegal	n/a	0	0.2	0.5
Ghana	(.)	n/a	(.)	0.4
Kenya	(.)	(.)	0.2	0.7
Nepal	n/a	0	0.1	0.7
Tanzania	n/a	(.)	(.)	0.2
Sudan	n/a	0	0	0.7
Mozambique	n/a	n/a	(.)	0.2
		t-values		
India	1.155	0	-0.078	0.635
Nicaragua			2.254*	2.542*
Pakistan		0	-0.078	0.363
Senegal		0	0.699	-0.454
Ghana	-0.577		-0.855	-0.545
Kenya	-0.577	0	0.699	-0.272
Nepal		0	-0.078	-0.272
Tanzania		0	-0.855	-0.726
Sudan		0	-0.855	-0.545
Mozambique			-0.855	-0.726

Source: UNDP 2001 for top part of table.

* Significant at 95 percent level.

Note: Where entries in the TAI are designated as being less than half the unit shown, I have assigned them a value of zero.

would entail a basic revision of this index, taking into account the criticisms that were advanced in previous sections of the paper. The second avenue that needs to be followed would involve the creation of an entirely different index, one that would be oriented specifically toward the rural poor and the achievement of the Millennium Development Goals.

Revising the TAI

As I have described it, the major problem with the TAI is that because of its pronounced developed country/urban bias in many dimensions it excludes the vast majority of developing countries and, even for the poor countries that are included, the scores that are recorded in those crucial dimensions are not significantly different from the mean. It seems clear, therefore, that the TAI does not even come close to meeting its stated goals of being useful to all developing countries and being able to discriminate among even the technologically most backward of those countries. It seems equally clear, by symmetrical reasoning, that in order to redress these problems the developed country bias that so pervades the index needs to become much less pronounced.

Most important, the capability to innovate as measured by patents and royalties needs to be replaced by a concept that embraces a more general process of learning at earlier phases of the acquisition of technological capabilities (earlier, that is to say, than the capability to innovate in the sense used in the TAI). As part of this more general process of learning, one would want to include, among other things, the increases in capabilities that emerge from the use of (new) technologies, the adaptations of such technologies to local circumstances (that are sometimes referred to as "minor innovations"), and the cumulative effects of these processes over time. The idea, then, is to capture increases in knowledge gained in a particular country rather than just the part that gives rise to innovations. And what probably best reflects the outcomes of these gains in knowledge is the change in total factor productivity (that is, the component of growth that cannot be accounted for by the growth of physical and human capital).[7]

Fortunately, there is now at least one data set that contains information on changes in total factor productivity for a wide range of developed and developing countries. In particular, Steven Baier et al. (2002) have compiled data on this topic for 145 countries, using 10 years as a minimum period of observation. While it is, of course, true that total factor productivity includes more than just knowledge (resource allocation and economics of scale being just two such additional factors), the data now emerging on the topic seem to be far superior to the highly limited focus on technology creation in the TAI.

Developed country bias was also found to be at work in the choice of indicators that measure just the number of different modes of communication. In particular, the indicators for Internet hosts and telephones assume that access to these "new" and "old" innovations occurs in the same way (namely, through individual ownership) in both developed and developing countries. Yet, I was at pains to show that in at least the rural areas of developing countries the Internet and fixed-line telephones (which often take the form of payphones), are shared among large numbers of (often poor) inhabitants, who, personally, own neither of these modes of communications (and although I did not single out mobile phones, the same pattern of gaining access to their services via sharing seems to be no less widespread). Ideally, therefore, a revised TAI would capture access to, rather than ownership of, these various technologies. And, indeed, for some countries access measures do exist, as shown, for example, in table 3. (In the African context, South Africa is perhaps the only country that collects access data as part of household surveys). At this stage, however, it seems unrealistic to rely on access rather than ownership data across a wide range of developing countries. With regard to fixed line telephones, an imperfect but nonetheless useful proxy for the extent of communal sharing would be the number of payphones per country (data that are available from the ITU). This variable would go at least part of the way toward offsetting the pronounced degree of developed country bias that currently besets the indicators now used by the TAI with respect to the Internet and telephones.

Partly because it is an indicator that is pitched at too high a level for many of the poorest developing countries (in Africa and South Asia), the lack of data on tertiary science enrollment ratios helps to exclude these countries from the ranking. By pitching this indicator at the lower level of science graduates from high school, more data will be available and the problem of exclusion will be ameliorated. This too can be regarded as a means of offsetting the developed country bias in the selection of indicators for the TAI.

The last line of criticism that was leveled at the TAI had to do with the distinction between the availability of commodities, technologies, and schooling on one hand and the achievements that are actually derived therefrom on the other. With reference to the Internet and the number of years in school, I showed that there can be a vast difference between the potential available gains and the actual benefits that are realized in practice. It is of course the latter concept that better reflects technological capabilities, but it is often far more difficult to measure than the former. In the case of the Internet, though one might have expected to find a substantial body of research on the gains derived from this technology in different countries, in reality one can point to only a few studies in the context of developing countries (one of which was described in relation to table 2). As regards education, however, the situation is much more promising, in that concerted international efforts are underway to measure, among other things, the scientific achievements of students at the same grade level. The most extensive of these efforts is the *Trends in International Mathematics and Science Study*, 2003, which compares achievements across forty-six countries drawn from developed, developing, and "transitional" regions. For the 2007 study, it is expected that the number of participating countries will increase to sixty, at which time there will be more scope for including achievements in cross-country indices.

An Index of Rural Capabilities in Developing Countries

Even a TAI that was revised along the above lines, subject to no constraints regarding data availability, would not help to redress the need for an index of technological capabilities that was rural in character and capable of connecting with the debate over the MDGs (as noted above). Nor, unfortunately, can one appeal to the literature on rural development, which for the most part has not embraced the concept or the measurement of technological capabilities. A still further problem is that many, if not most, economy-wide measures in developing countries fail to include a disaggregation at the level of urban versus rural sectors. In the crucial area of education, for example, Michael Lakin and Lavinia Gasperini (2003, 81) have pointed out that "[i]nternationally comparable . . . statistics rarely distinguish urban and rural data." More generally, the World Bank itself has drawn attention to the fact that

> [i]mproved monitoring of rural development will require a significant effort in data collection on a long-term basis. The developing world is replete with ad hoc surveys, but these do not provide consistent coverage of the different

> aspects of rural development. . . . Improving the quality of the rural data system is not only imperative for the World Bank, but also for client countries and the donor community. Donors and developing countries alike should embark on concerted efforts to develop capacity in countries, where they do not currently exist, to collect, maintain and measure rural data/indicators. (The World Bank 2000, 11)

Taken together, the difficulties that have just been described mean that constructing an index of rural capabilities will certainly be a far more difficult task than it is at the national or urban levels. Indeed, it is all too easy to bemoan the absence of data disaggregated by sector, or simply unavailable, for the many indicators that one might want to include in a rural index. A more constructive endeavor, however, would seek to indicate data that *could*, in one way or another, serve at least as a foundation on which to construct an index of rural technological capabilities (or, in some cases, an index that can already be used). It is to such an endeavor that the rest of the paper is in fact devoted.

Selected Data Sources for Indicators of a Rural Technological Capabilities Index

What needs to be emphasized at the outset of this section is that the data sources referred to do not purport to be in any sense comprehensive. They should be regarded, rather, as just a first step in the direction that, I hope, others will be able to extend and improve upon. I have divided my tentative findings into four categories, namely, those dealing with productivity, those dealing with the diffusion of an "old" technology, those related to infrastructure, and those dealing with educational achievements.

Production Capabilities–Although data on output per person employed in agriculture can be readily obtained (via, for example, ILO sources), what concerns us is, rather, the productivity of small farms. For, out of the three quarters of the world's poor that live in rural areas, a good many of them earn their livelihood on small-scale farms. What are required therefore are farm-level data for developing countries, which, however, are much less easy to come by. Giovanni Cornia (1985), nonetheless, has used FAO farm level information to estimate land and labor productivity across farms of different sizes for fifteen developing countries.

As far as specific production capabilities are concerned, biotechnology is arguably more relevant to resource-poor farmers than IT, which has certainly not been designed for the circumstances prevailing in rural areas. The former type of new technology, by contrast, "holds 'enormous' promise for helping poor people around the world–just as the Green Revolution of the 1960s and the 70s helped to raise millions of people out of poverty" (FAO 2004). "An estimated 7 million farmers in 18 countries–more than 85 per cent resource-poor farmers in the developing world–now plant biotech crops" (ISAAA 2004). And given the fact that the majority of resource-poor farmers are women, the impact of biotechnology has an impact on gender as well as poverty. Both the ISAAA (International Service for the Acquisition of Agri-Biotech Applications) and the FAO's BioDeC site contain information regarding the status of biotechnologies in different countries.

For large numbers of countries, therefore, one might have to make do with data already available on agricultural productivity or potential surrogates such as the number of tractors or the extent of fertilizer use.

Diffusion of "Old Innovations"–As noted above, the TAI uses the number of telephones as the "old innovation" in the area of communication technologies. Quite apart from the difficulties with this indicator that have already been mentioned, the point to be stressed here is that, from the standpoint of the rural poor, radios rather than telephones are much the more relevant mode of communications (and rural data are much more plentiful in the case of the former). According to Pigato 2001, for example,

> Data from DHS [Demographic and Health Surveys] taken during the period 1991-99 from 26 low-income countries in SSA and South Asia indicates that about 5 percent of urban households have telephone ownership compared with 0,18 percent of rural–or 3,4 percent of the total. By contrast, radio ownership reaches . . . 40 percent of rural. . . . Again, DHS data suggests that telephone ownership is confined to only some 12 percent of the richest quintile in SSA and South Asia. The picture is different for radio ownership. Radio is owned by about 10 percent of the 20 percent poorest households and *by about 40 percent of households in the second poorest quintile.* (Emphasis added)

To the extent, therefore, that one is concerned with the poorest quintile of the population in these twenty-six countries, it is to radio that one needs to look as a means of communicating helpful information, in other words, information that in one way or another helps to improve the functionings of this segment of the population. One important way in which this is already occurring takes the form of blending the information available on the Internet with the wide reach of the radio in rural areas. In Sri Lanka, for example, radio presenters at Kothmale community radio station search the Internet on air for relevant information, which is then translated and interpreted by local volunteers (such as doctors and teachers) in a way that is accessible to those living within broadcast range.

Even without the advantage of an Internet connection, however, community radio has several distinctive features that make it especially useful for meeting the MDGs in deprived rural communities. In many such communities, for instance, community radio is the source of market prices for locally grown crops. In terms of providing information, including education, community radio is–almost by definition–best suited to provide listeners with what they actually want and need.

What ideally need to be measured, therefore, are not only the number of radios in (poor) rural areas but also the extent to which those areas are served by community as opposed to public, or commercial, radio stations. As regards the availability of rural radio receivers, household surveys seem to be the richest source of data at the country level. These may take the form of demographic and health surveys, as was the case in the citation at the beginning of this section or, more typically, from household surveys in particular developing countries (of which the World Bank has the most plentiful supply). In one case, that of Ghana, I found rural radio ownership data for different gradations of poverty in a Core Welfare Indicators Questionnaire Survey.[8]

Suitable data for community radio are difficult to put together, mainly because knowing only the number of stations per country (knowledge that is available for some countries from the World Association of Community Radio Broadcasters) says nothing about the numbers of listeners that are actually served. Ultimately, therefore, the availability of radios per rural household may need to be used for a wide cross-section of countries.

Educational Achievements–A recurring theme throughout this paper has been the need to move away from measuring merely "inputs"–such as years of schooling, numbers of technologies adopted, and number of scientists–toward measuring the actual achievements associated with these and other inputs. In poor, rural areas in developing countries, there are a wide variety of contextual variables that bear heavily on the relationship between educational inputs and educational achievements. In general, one may expect that this relationship will be less favorable to students than it is in urban parts of developing countries or, more tellingly, in the developed countries themselves. The problems are inter alia that

> [w]hen they do exist, rural schools in remote areas are often in need of repair, poorly equipped and staffed with inadequately trained and underpaid teachers.
>
> The curriculum and sometimes the language of instruction are not suited to local conditions. Therefore, "school learning" may appear quite irrelevant to poor rural children in comparison with their more immediate survival needs. Often, programmes targeting rural adolescents and adults are not well organized, nor well adapted to local learning needs and depend on untrained or inadequately trained, underpaid personnel. (Atchoarena et al. 2003, 391)

Or, again, in a useful critique of the "input" approach to education, Lakin and Gasperini (2003) pointed out that "[e]ffective access to schooling involves more than initial enrolment. Regular attendance is a minimal requirement, which unfortunately is often not met in rural areas. Health problems, malnutrition, domestic demands on children's time and seasonal demands for their labour in the fields all take their toll on attendance and therefore on learning achievement" (86).

What, then, do we actually know about rural learning achievements? Taking, to begin with, children in school, it is clear even from surveys of a limited number of countries that learning achievements may be poorly correlated with per capita incomes. MLA data, for example, show that one of Africa's richest countries, Botswana, performs very poorly in relation to other, strikingly poorer countries from the region. No less telling is the fact that the two countries with the highest and lowest achievement scores have similar income levels (Chinapah 2003). We also know that for children in grades 3, 4, and 5 urban achievements are consistently higher than rural. One of the most comprehensive demonstrations of this "urban bias" in learning achievements is to be found in survey results obtained by the MLA for forty-four developing countries drawn from different parts of the Third World (MLA 2002). These data are especially interesting because they reveal urban-rural differences across literacy, numeracy, and life skills for each country in the sample (certain data gaps notwithstanding). Not only, that is to say, do they relate to education, which is widely recognized as one of the most critical variables in meeting the MDGs but they also provide much more information than the usual "input" data for this variable (such as years of schooling), though such data are far more widely available.

Infrastructure–In the form, for example, of paved roads and rural post offices, infrastructure has an important influence on rural productivity in developing countries and should form part of any index of technological capabilities of the kind here being considered.

Conclusions

It has long been recognized in institutional economics that technology is the driving force behind economic development, and this recognition has been confirmed by the empirical growth literature (Denison 1962). There is thus every reason to understand the technological features of countries at different stages of development.

In recent years, a number of attempts have been made to construct indices of technological capabilities that include both developed and developing countries. (Because these indices are rather similar, not much is lost by focusing on just one of them, which for the purpose of this paper is the Technology Achievement Index compiled by the UNDP). These efforts are to be commended for seeking to collect comparable data over such a wide variety of countries. And the outcomes, as denoted by the values of the index, are certain to be of interest to countries such as Korea, Brazil, and India, which are already quite heavily engaged in the type of technological activities in question. From the point of view of the majority of developing countries, however, I have suggested that these measures are largely irrelevant, because they exhibit a pronounced degree of developed-country bias that translates, within such countries, into a bias in favor of the modern, industrial sector (in a manner envisaged in the 1960s by Myrdal and Seers). I further suggest that the extent of this bias will tend to be larger the more circumstances in the developing country differ from those in the rich. I find that the circumstances prevailing in the latter group of countries insert themselves into the new indices (with the TAI being used as the example thereof) in a number of different ways. One is by the choice of indicators (such as patents) that relate only to the most advanced of the developing countries (such as Korea, India, and Brazil). Another takes place through a process described many years ago by Myrdal (1968), namely, of assuming that there are concepts which apply to all countries alike, regardless of how different the relevant goals, institutions, attitudes, and other factors may actually be between rich and poor countries, and regardless of how far these differences invalidate the use of a certain concept in one context but not another. What these influences are shown to cause, is, among other things, that the TAI fails to achieve the very goals it itself sought to achieve, namely, to reflect the policy concerns of all countries, rich and poor alike, and to be useful for the latter.

Having argued this point in quite some detail, I then took note of two different directions that further work in the area might profitably take. The first would be a revision of the TAI itself and, more specifically, an attempt to lessen the bias with which it is so strongly associated. Perhaps most importantly, the capability to innovate as measured by patents and royalties needs to be replaced by a concept that embraces a more general process of learning and a wide variety of capabilities. Even a TAI revised along the lines I suggest, however, would not help to redress the pressing need for an index of technological capabilities that helps to throw light on and alleviate the problems confronting those who live (often in poverty) in rural rather than urban areas. Such an index, one might have thought, could play an important role in the search for ways of meeting the Millennium Development Goals, which feature so prominently in the discourse now being conducted among a wide variety of international institutions. Though it is not difficult to conceive of a range of indicators that a pro-poor, rural index of technological capabilities might reasonably contain, the major problem in finding the relevant data on a cross-country basis is likely to be the tendency in many areas of development to collect and present statistics only at the national level (one of the more irritating examples of which is the absence of any data on specifically rural telephony at the International Telecommunications Union).

Notes

1. See footnote below for a discussion of these.
2. The measures in question are the World Economics Forum Technology Index, the UNIDO Industrial Development Scoreboard, the Science and Technology Capacity Index developed by the Rand Corporation, and the ARCO Index associated with Danielle Archibugi and Alberto Coco.
3. Archibugi and Coco (2004b) have compared the various measures listed in the previous footnote, together with the TAI index, and to this end they compile a synopsis of the major features of the approaches in question. This "shows at a glance that the various approaches contain significant similarities. In fact many indicators are identical, signalling the achievement of a certain consensus amongst scholars on what are the most significant components of technological capacity" (8, emphasis added). All the approaches, for example, take "the use of patents as an indicator of technology creation, . . . ICT indicators for technological infrastruc-

tures and diffusion; and tertiary education in science and engineering as an indicator of human skills" (15). I argue below that these are precisely the indicators that are least relevant to the majority of developing countries, though one should recognize in this regard the inclusion in ArCo of a literacy variable, making it somewhat more reflective of developing country circumstances.

4. As discussed in detail in the previous note.
5. The catch-up idea is most closely associated with Abramovitz 1986.
6. The UNDP (2001), for example, tends not to conclude from the unavailability of relevant data that more work should be devoted to the collection of such data (46).
7. The use of this well-known concept is apparently not even considered in the conception of the TAI. Note that not all increases in knowledge promote growth and some may do so indirectly rather than directly.
8. Extracted from the country survey database of the World Bank.

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